Sensor arrangement for seismic waves

The invention relates to a sensor arrangement as indicated in the introductory part of ~~claim 1~~, for receiving seismic waves, which are reflected from geological formations below the seabed, on which seabed a plurality of sensor nodes are placed, preferably in an orderly manner. In addition, it comprises a method of managing a seismic mapping system.

Background

For sensing seismic pressure waves, and shear waves in particular, the sensor nodes must, in principle, be in contact with a solid medium. In a marine offshore environment, this implies collecting this kind of data on the seabed, in contact with the subsea sediments. In this context, shear waves or converted seismic waves have other characteristics for describing formations and hydrocarbon reservoirs, than the traditional pressure waves alone. In a marine context, pressure waves are traditionally collected by using hydrophone sensor cables, being towed behind a vessel that also expels regular pressure pulses from air guns.

In a marine context, shear waves and converted shear waves are usually obtained by generating pressure waves with a pressure pulse from air guns at a surface vessel. When such pressure waves strike the seabed and the various geological interfaces in geological formations below the seabed, some of the pressure wave energy will transform into reflecting shear wave energy or converted shear waves, which are absorbed in sensor nodes that are deployed down into the seabed. Since water does not have shearing strength, it cannot carry shear waves, as can solids.

To obtain mapping value of the geological formations, the sensor nodes must be placed in organized matrix patterns in large numbers on the seabed, so that the reflected pressure waves and converted shear waves together can contribute to an accurate image of the geological seabed formations. In this context, an image signifies a geometric three-dimensional representation, which gives information on petrophysical characteristics of geological reservoir formations and the fluid content of these.

Of known systems, there are mainly two types; so-called "OBS" or individual seabed seismometers and multiple component seabed cables. OBS-units are dropped from the surface and sink freely down onto the seabed. The geophones are placed on the inside of a glass ball, while

geophones, hydrophone, collection electronics and collected data float up to the surface, where they are collected. An iron frame platform is left on the seabed. OBS is used for rough geological mapping based on seismic refraction.

Multiple component seabed cables normally comprise three-component geophones with gimbal suspension and hydrophones lying inside and along a cable, or in windings of a cable. The cables are laid or rolled down onto the seabed by dynamically positioned vessels on the surface, but in some cases they can be pulled along the seabed. The collection of pressure- and shear wave reflection data occurs with the same method as with surface cables.

Object

The main object of the invention is to provide a sensor arrangement, which combines the demands for reliable and detailed registrations, i.e. absorption of reflected seismic waves of an area, with the request for equipment that is easy to place on the seabed.

Another object is to provide a sensor arrangement with a sensor element, which can be lowered into the sediments on the seabed and which is unaffected by a support and control unit, while ensuring directional sensitivity, independent of the position. The sensor arrangement should be small, compact and light. Additional objects of the invention appear from the example description.

The invention

The invention is stated in claim 1, whereas claims 2-11 state particularly advantageous features of the invention. The invention further comprises a method for operating a seismic mapping system, as stated in claim 12.

Further details of the invention will become apparent from the following example description.

Example

The invention is described below in more detail, with reference to the drawings, in which

Fig. 1 is an exploded perspective view of a sensor arrangement according to the invention, with a sensor node in connection with a control unit,

Fig. 2 is an exploded perspective view of an embodiment of a sensor node, and

Fig. 3 is a schematic perspective view, which illustrates the placing of a number of sensor nodes in a squared pattern, and how a wave generated from the surface is reflected towards a node from a geological formation below the seabed.

Fig. 1 shows a control unit 11 with a cigar-shaped housing 12 placed onto a pair of runners 13 with a bend in both ends. The cigar-shaped housing 12 has a cylindrical central part 14 with end flanges, and two hemispherical shaped end-domes 15 attached to the end flanges. The housing 12 is attached to two opposed, divided supports 16A and 16B, which on the upper side are joined with a rail 17 that holds a gripping bow 18. With this gripping bow, the control unit 11 can be lowered down onto the seabed at defined positions. This will be described below.

The control unit 11 contains a computer with a storage medium, clock, telemetry system and batteries. It makes continous recording of seismic data with a given sampling frequency possible. Hydroacoustic communication makes it possible to collect control data from saved seismic data on a hard disk, at discreet points in time. Only data chosen in advance is recorded y telemetry, and this data consists of two types: 1) system data and 2) seismic data, which are processed further. System data can be information about battery status, data storage volume and tiltmeter data. While cable connection has limited capacity for data transmission and quality control, the transmission capacity is now limited and the need for good methods and routines for quality control has increased.

Further, Figure 1 shows a sensor node 20, which is connected to the control unit 11, with an acoustic insulated cable 21, i.e. a cable, which cannot transfer mechanical vibrations. The sensor node 20 can be carried together with this during the deployment, as will be described below. In Fig. 1, a transducer 19 is also shown, for transmission of data.

Fig. 2 shows a more detailed example of a sensor node 20, which provides a sensor system. The sensor node 20 includes a lower main part or skirt, a geophone housing with three geophones, a tiltmeter that measures angle in relation to the coordinates X and Y, a hydrophone and a grip element for a ROV. These parts will be described below in more detail.

The lower main part comprises a cylindrical skirt 22, which at its upper part is terminated with a plate ring 23 that is fixed, for instance by welding, so that it has the shape of an inverted bucket

with an opening in the bottom. A skirt 22 with a shape that deviates from an ideal cylindrical shape, for instance a multiangular and/or slightly tapered shape, can can also be used.

The skirt 22 in the example is cylinder shaped for being direction insensitive with regard to seismic waves, and simultaneously for achieving a good coupling to the seabed sediments. Because of the thin walls of the skirt 22, the skirt will cause small mass movement, but simultaneously have a large contact area against the sediments on both sides (inside and outside). The skirt can advantageously be of aluminum, for achieving optimal contact/binding. Aluminum binds well to clay minerals in the sediments.

The diameter and the length of the skirt can be of the same dimension for instance 200 mm, with a wall thickness of 5 mm. A V-shaped outlet 24 is made in the upper edge of the skirt 22, partly for giving space to the cable 19, and partly for letting out sediments and water when deploying. On the diametrically opposed side, there is a notch 25 in the edge of the skirt 22 for ensuring sediment discharge.

In the upper part of the cylindrical shaped skirt 22, and attached to the plate ring 23, there is placed a geophone housing 27 of cylindrical shape and an upper flange 28 for a cover 29. In the geophone housing 27, there are placed three component-geophones 30, 31, 32, which are positioned with a 90° angle in relation to each other, and a coupling card 33 with electric components and couplings. The geophone housing 27 has an attachment plate 34 for the cable connection 35, with an opening for the cable 21.

On the cover 29, four upwardly projecting poles 36 are evenly distributed at the outer edge, and define a cage 37 for a hydrophone 38. The hydrophone 38 measures pressure changes right above the geophone housing 27, for instance 10-15 cm above the seabed, in pure water zone. It shall not have sediments surrounding it.

A plate 39 is mounted above the poles 36, which carries an upwards projecting grip 40, for a gripping tool on a remotely operated vehicle (ROV). The sensor node 20 can in this way be deployed from a remotely controlled vehicle with a general arm or by making a special deployment tool (ROT) for deploying the sensor node. This is in particular relevant in shallow waters, with a depth of some tens of meters.

The skirt 22 is lowered into the seabed sediments, so that the lower part of the geophone housing 27 has a good connection to the surrounding sediments. The skirt 22 ensures a minimal change in the sediment characteristics, as little sediment mass is relocated during deployment. This makes the skirt-design suited to both a hard and a soft seabed. The coupling of the skirt 22 to the upper 10-50 cm of the seabed sediments represents the geophone coupling to the sediments just below the seabed. The skirt is lowered down to the lower part of the geophone housing if the seabed is hard, or down to the upper part of the skirt if the seabed is softer (upper edge of the skirt).

The sensor nodes 20 are then deployed as vertically as possible (less than 5 degrees off vertical). The direction/heading (compass direction) in relation to north is measured from the ROV. This makes it possible to conduct a full rotation in relation to measured data. This is much more accurate.

Under extreme conditions with considerable current on the seabed, the control unit can be provided with extra weights and spikes that extend into the seabed, so that it is held in position. (Experience with the aforementioned is in 4 knots current at a river mouth).

For large water depths towards 2000-3000 m, the control unit 11 must be modified for such depths. The rest of the sensor node 20 can remain the same.

Fig. 3 shows an example of an arrangement with several sensors in a matrix pattern on the seabed 41, where each sensor node 20 is connected to its own control unit 11. In this way, it is possible to map the pressure wave reflections 42 and the shear wave reflections 43 in a sheet pattern. On the basis of this, with appropriate signal processing, one can draw conclusions about the geological formations below the seabed including the fluid content, among other things. A typical distance between the sensor nodes 20 can be 300-500 m. Numeral 44 indicates a vessel that generates seismic waves 45.

The sensor node 20 shall, in principle, be small, compact, and light weight. Its specific weight may be the same or less than the specific weight of the sediments in which it is deployed. The size and shape of the skirt can be adapted to various seabed conditions. The skirt 22 and the grip 40 of the ROV are modular and can easily be replaced with corresponding parts with different

size and shape. Manufacturing the skirt in aluminum yields particularly good contact to the sediments in the seabed.

When the sediments are hard, the shape of the skirt 22 can be altered by reducing the skirt length and increasing its diameter, to achieve the best possible coupling. When the bottom is rough or particularly hard, the lower part of the skirt may have teeth to achieve a better contact to the seabed sediments, where appropriate.

For soft seabed sediments, it is appropriate to increase the skirt's diameter and possibly also its length, to achieve the best possible coupling. In any case, the sensor nodes 20 shall have the lowest possible centre of gravity, i.e. the centre of gravity should be on or, even better, below the seabed level. The weight of the sediments inside the skirt is included when determining the centre of gravity. The shape of the skirt ensures a stable coupling of the sensor node to the seabed, even with some lateral variation of the sediments along the bottom.

As an alternative to the skirt 22 of plate material, a ring layout of poles, with or without spaces, can be used.